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14. ABSTRACT

The ultimate goal of this project is to create a user-friendly and effective method to assess surgeon readiness, after new training and after prolonged periods without training or practice, to enhance patient safety. In this project, a FLS trainer is instrumented with motion tracking and sensor data capture. The data captured is automatically analyzed by our software algorithm to provide objective skill assessment and performance feedback to the surgeon. Progress on the laparoscopic simulator development and testing is reported here.

15. SUBJECT TERMS

Reset training, data-driven optimization of surgical skills, environment training simulator, automatic error monitoring, real-time performance feedback, laparoscopic surgery

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INTRODUCTION

The ultimate goal of this project is to enhance patient safety by creating an objective, user-friendly and highly effective technology platform to assess surgeon readiness after new training and after prolonged periods without training or practice. A real-time analysis of individual performance data could be used to detect physical fatigue, impairment or other surgeon-factors that may threaten patient safety. Our integrated plan involves the development of automatically graded surgical tasks based on the FLS skills curriculum. In this project, a FLS trainer is instrumented with motion tracking and sensor data capture. The data captured is automatically analyzed by our software algorithm to provide objective skill assessment and performance feedback to the surgeon. This concept of an integrated training program with state-of-the art simulation technology will ultimately lead to real-time surgeon-factors assessment and surgeon-specific reset training to enhance military surgeon readiness, improve outcomes and increase patient safety.

BODY

This project was funded as of 21 July 2008. The contract expiration date was 31 March 2012 (research ending 29 Feb 2012).

A final report for this project is attached with emphasis on progress made during the period August 2011 – Feb 2012 is described below.

A no-cost extension of time for the original one-year project was granted on June 18, 2009. The approved revised statement of work as is presented in Table 1. An additional no-cost extension of time and additional funding for a half time engineer was requested 08 October 2010. During the period of consideration of the funding request, data collection continued but analysis and engineering work was delayed. The no-cost extension of time and additional funding was approved by contract modification on 03 May 2011, with a final contract extension of time approved on 25 Jan 2012. The work for the additional funds was directed toward Task 4 with the addition of integrating augmented reality feedback with the FLS trainer.

TABLE 1: STATEMENT OF WORK: Deliverable tasks
1. Describe a methodology to define and objectively measure basic laparoscopic skills in surgeons (based on the FLS curriculum).
2. Provide preliminary data demonstrating “proof of concept” that a physical-based laparoscopic simulator can reliably differentiate between novice and expert.
3. Describe a methodology and provide preliminary data to document individual-specific laparoscopic skill deterioration during prolonged absence.
4. Describe a methodology to employ augmented reality technologies to support individual-specific retraining of basic laparoscopic skills following prolonged absence. To integrate augmented reality feedback during the training process.

In previous annual reports, initial progress on Tasks 1, 2 and 4 were reported. These reports described steps taken to determine the scope and design of simulated tasks, development of the instrumented simulator, refinement of task metrics, and incorporation of augmented reality technology. Technology development time and funding limitations have limited the ability to explore the impact of prolonged absence on skill degradation on subjects that have reached proficiency (Task 3). This report provides an abstract of simulator development and task metric measurements below for orientation to the newly reported data analysis.

TASK 1: **Describe a methodology to define and objectively measure basic laparoscopic skills in surgeons (based on the FLS curriculum)**

Determine scope and design of simulated tasks

Work was largely completed on this task during the 2009 reporting period.

The design of our instrumented simulator box was based on the SAGES FLS laparoscopic trainer box. Like the SAGES FLS curriculum, the simulator curriculum is proficiency-based, whereby trainees are oriented to the materials and self-practice until expert-derived performance levels are reached. Like the FLS trainer box, the instrumented simulator allows practice of technical skills to improve dexterity and psychomotor skills. Key technical skills identified for training during simulated laparoscopic manipulation include:

- Eye-hand coordination
- Ambidexterity
- Depth perception
- Complimentary use of both hands (bimanual skills)
- Familiarity with common laparoscopic surgical devices
- Instrument navigation and transferring
- Accuracy of instrument placement
- Proper application of force appropriate to task

The skills testing tasks that were the most amenable to study for implementation with our instrumented simulator include pegboard transfer, pattern cutting, and intracorporeal knot tying. These tasks were chosen based on variety of instrumentation used and skill types tested, ease of implementation during the project time constraints, and the ability to incorporate sensors on instruments. For each task, the metrics to be measured were modeled after those scored in the FLS curriculum tests, and include timing of each exercise, accuracy and efficiency of performance, and error tracking. In addition, other metrics are being calculated which can be used to deconstruct specific movement patterns of the participants.

Instrumented Simulator Development:

Significant time was invested into developing a graphical user interface for the FLS so that anybody could setup the simulator and test subjects without knowledge about the software. Instructions were included with the software and given to experimenters at Wayne State University (WSU) and Beaumont Hospital for data collection.

We have developed software to automatically gather position and orientation data from magnetic trackers attached to the laparoscopic tools during subject trials. Figure 1 shows the laparoscopic tools with the attached sensors (trakStar, Ascension Technology Corp.) that allow for the tracking of the tooltips and also of the gripper state. Internal to the FLS trainer is a camera and LED illumination source as well as a magnetic transmitter. The magnetic transmitter is placed in the far left corner of the trainer housing. The transmitter does not interfere with the work envelope and is out of view of the camera. The equipment is placed on a plastic table to minimize interference with the magnetic tracker.

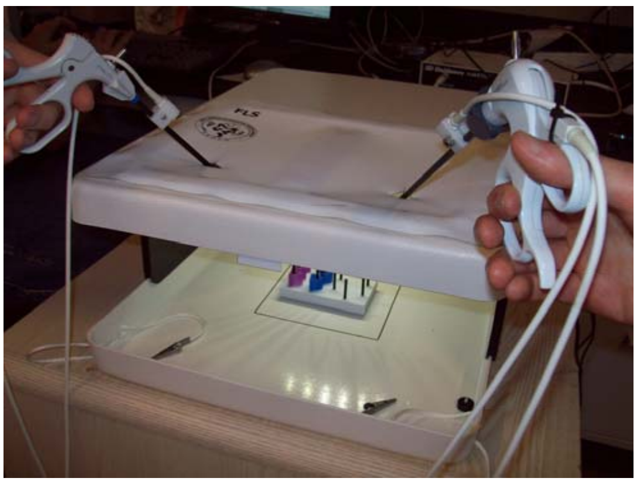


Figure 1: FLS trainer with magnetic sensors on the tool shaft and handles. This allows tooltip tracking and gripper state.

Each laparoscopic tool is fitted with two magnetic trackers that determine the position of the instrument in space and if the trigger is open or closed. Figures 2 a and b illustrate how the sensors attach to the laproscopic tool using a mounting bracket. Currently the handle sensor is attached with a wire tie and the shaft sensor is held in place using two machined brackets as seen in figure 2b. Figure 2c illustrates the mounting bracket (half) CAD rendering.

Figure 2: a: Handle Sensor b: Figure 3 Tool Sensor c: Mounting Bracket

The complete system consists of a the FLS trainer with magnetically instrumented tools, Magnetic Tracker, CRT monitor, and a PC. Figure 3 illustrates the equipment setup.

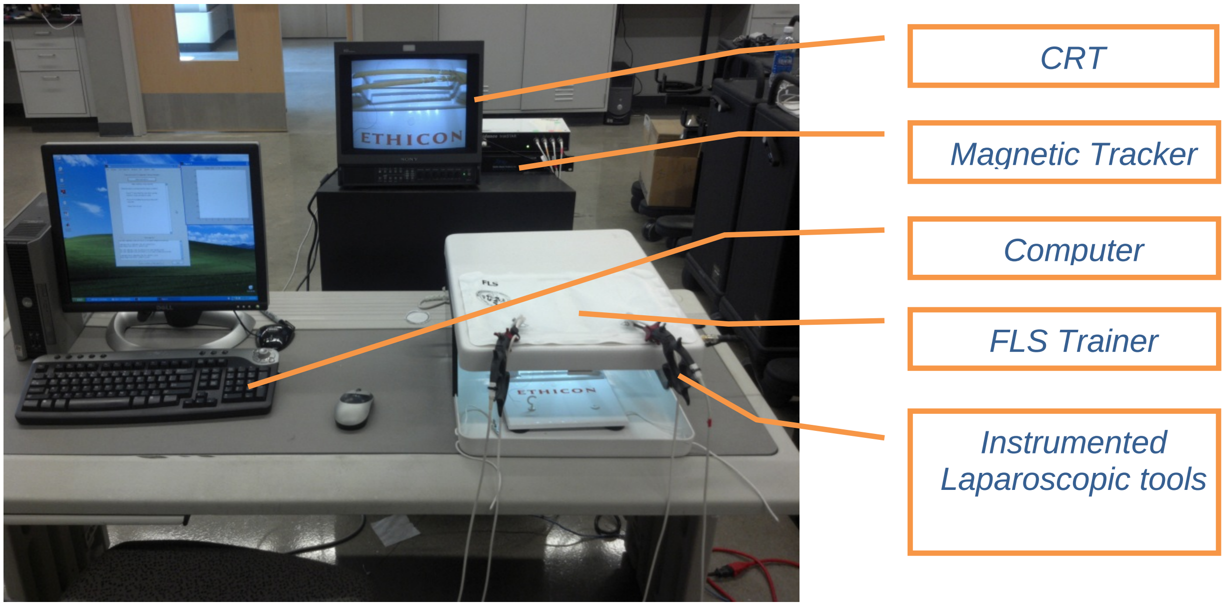


Figure 3: FLS Laboratory Setup

Software

Figure 4 is a screen capture of the software. The software was written in Matlab version 2009. During normal operation there are two forms of interest. The first form or controls form consists of a window that presents the user with operation instructions and allows the user to begin data collection. The controls form also contains menu items to initialize the magnetic tracker and calibrate the system sensors. Generally the software is run with one user performing the laparoscopic tasks an observer calibrates the instrument and triggers the recording. This can eventually be handled by one person with the use of a foot switch but this feature has not been implemented yet.

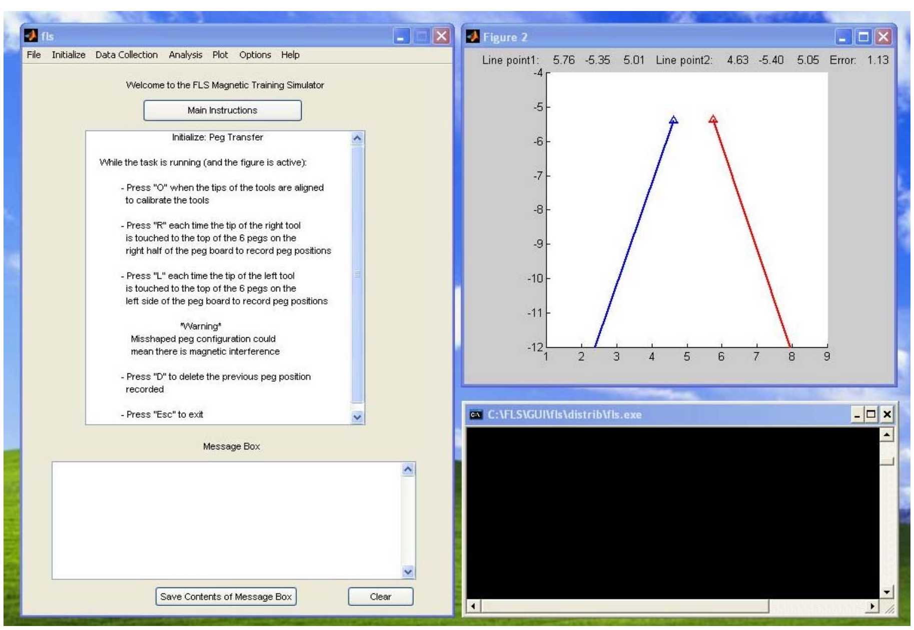


Figure 4: Software Screen Capture

The controls form has a menu items for initializing the magnetic tracker, calibrating the sensors for each task. The allowable tasks include Peg Transfer, Circle Cutting, and Intracorporeal Suture. The data collection menu item contains a sub menu for starting and ending recording tasks for all three tasks. The collected data is saved in a tab delimited text file. The data in the file consists of 25 values per sample. The data structure includes a timestamp, Left tool tip (x,y,z,roll,pitch,yaw), Left Handle (x,y,z,roll,pitch,yaw), Right tool tip (x,y,z,roll,pitch,yaw) and Right handle (x,y,z,roll,pitch,yaw). Each tool and handle is therefore represented by six degrees of freedom and from this information the positions of the tool can be reconstructed. Data gathering from this software is used to assess performance and feed into the augmented reality software kernel.

The software development also includes the calibration of the tool, sensors and the task platform (e.g. peg board for the peg transfer task and the circle for the pattern cutting task). The system will automatically capture the tool position and orientation and computes new metrics such as efficiency of movement and tool trajectory. The automatic data collection is important because all of the objective metrics will be derived from them. The tool trajectory data is stored and can be replayed as an animation as shown in Figure 5. This has an added advantage over the video file since you can change the perspective to any view and trace where the instruments have travelled.

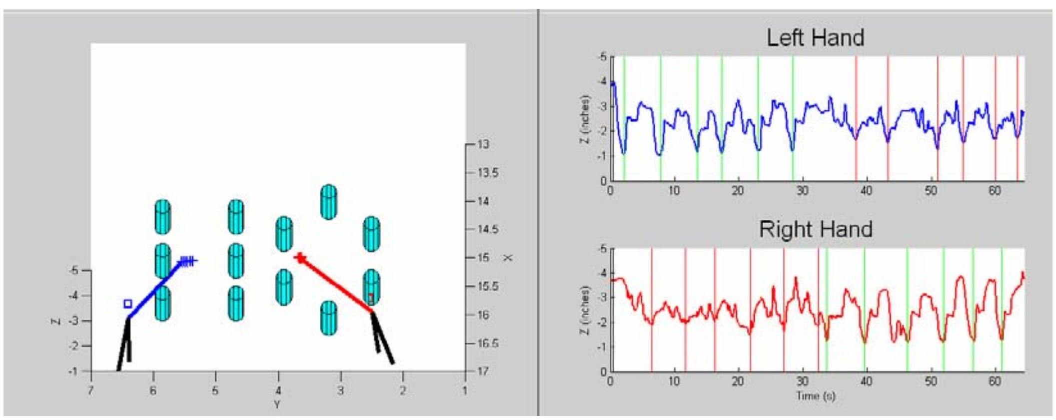


Figure 5: Left: 3D animation of the task, including instrument traces. Right: Analysis of tool tip height. The system uses this data to compute the task metrics.

Task Metrics

In this 2010 reporting period, significant refinement was made to the task metrics analysis. Table 2 has a list of metrics that are computed for the peg transfer task. Moreover, some of these primary metrics can be further broken down into subtasks such as picking up, passing and placing pegs as well as performance on any one individual peg. Data can be broken down by the subject's non-dominant vs. dominant hand performance (to determine degree of ambidexterity). We can also categorize errors into subgroups such as missed grasps and dropped pegs.

TABLE 2: FLS Task 1 (Peg Transfer) Metrics
• Time • Best Possible Time • Degree of Ambidexterity • Pathlength • Economy of Motion • Reversals • Working Volume • # of Pegs done out of sequence • # of Pegs done in parallel • Parallel Ratio • Errors • Secondary Task Performance

Similarly, for the pattern cutting task, metrics to measure the performance of the task are calculated. Image processing software was developed (Figure 6) that grades the 'quality' of the cut circle and gives the subject feedback as to how well the pattern was cut and what errors were made.

Before the task starts, the back of the gauze is marked at the 6 o'clock position for orientation purposes. After the task is completed, the back of the cut circle is marked with the subject ID and trial number. For calibration, we take a photo of an uncut circle. We then take a photo of the cut circle for the image processing analysis. Our computer program automatically measures the undercut and overcut regions and breaks it down by quadrants.

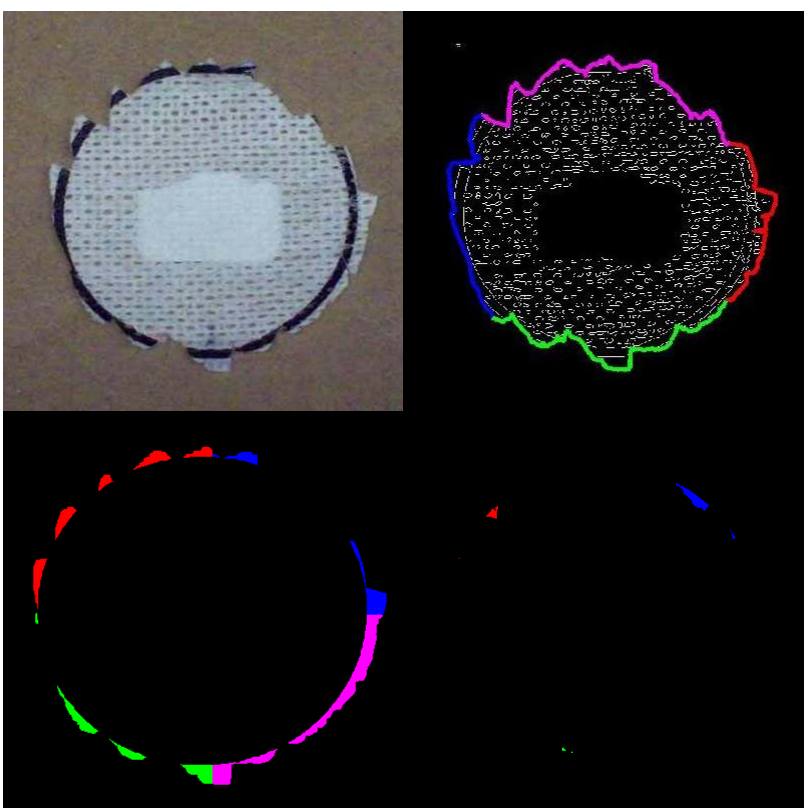


Figure 6:
Top Left: Digital photo of the cut circle.

Top Right: Image processing detects outline of the circle.

Bottom Right: Overcut Regions broken down by quadrant.

Bottom Left: Undercut Region broken down by quadrant.

Table 3 has a list of metrics computed for the circle cutting task. Moreover, some of these primary metrics can be further broken down by tool (grasper, scissors) or by sectors of the circle.

TABLE 3: FLS Task 2 (Pattern Cutting) Metrics
• Time • # of Tool Exchanges • Pathlength • Economy of Motion • Reversals • Working Volume • # of Cuts Made • Overcut Region • Undercut Region • Reversals • Scissors Tool Angle • Errors • Secondary Task Performance

TASK 2: **Provide preliminary data demonstrating "proof of concept" that a physical-based laparoscopic simulator can reliably differentiate between novice and expert**

In the 2010 and 2011 reporting periods, data was collected from 47 subjects in the peg transfer and circle cutting tasks. A total of 1388 trials of the peg transfer task and 214 trials of the circle cutting task were analyzed. Analysis of the novice learning curve and comparison with expert data within this subject group has provided significant progress toward the completion of Task 2, differentiation between novice and expert.

<u>Peg Transfer:</u>
One of the metrics that seem to be a good discriminator of skill among novices is the total pass time (i.e. how long does it take to pass the peg from one tool to another). Figure 7 shows the subject's total time vs. the total pass time. The vertical line represents the 48 second proficiency line that was the target. The horizontal line represents the cutoff that all subjects met who were proficient. More interesting is that the subjects who were not proficient rarely (~4%) met this horizontal cutoff. In fact, there were only 6 trials that met this cutoff. Such an extreme cutoff was not found for the pick or placement of peg data. This data indicate that passing a peg may be a good leading indicator of how well the subject will do on the task. It may be possible to conduct a training regimen where the subjects only practice passing a single peg 6 times back and forth to see if they fall under this horizontal cutoff. If they do, then it could mean that they are more likely to surpass the proficiency mark on the full test. This would in effect reduce the amount of training the subject would have to do. This metric may be

representative of test success because, as mentioned in the FLS guidelines, the purpose of the peg transfer exercise is to test eye-hand coordination, bi-manual coordination and depth perception. Passing encompasses all three skills, unlike picking or placing a peg which does not require bimanual coordination. This finding is particularly important when it comes time to create a reset training or parts training regimen.

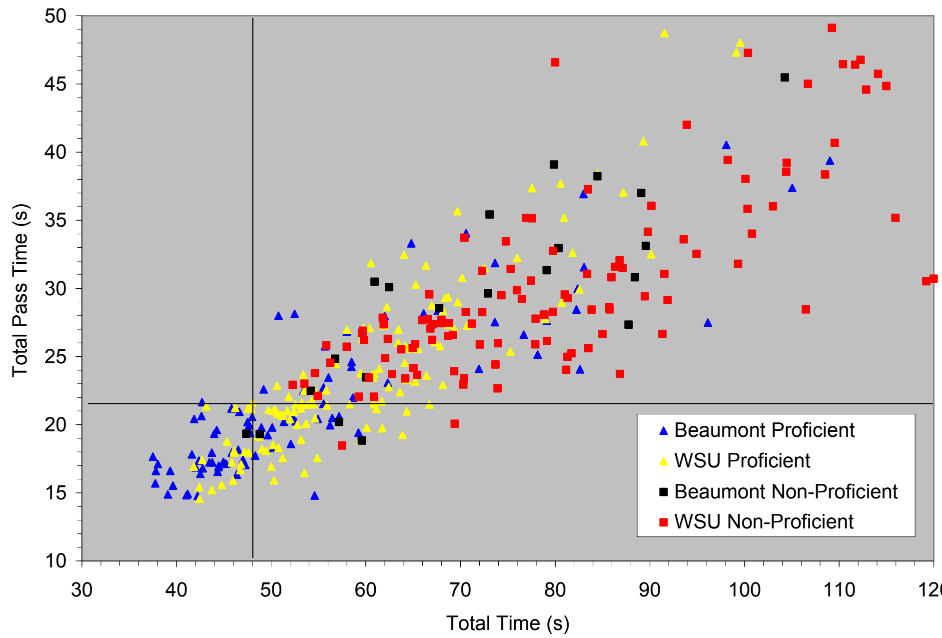


Figure 7: Scatter plot of the total pass time vs. total time for the peg transfer task. Subjects who have not reached the level of proficiency rarely (~4%) met the horizontal cutoff of 21.6s.

The data also indicates that some ambidexterity is required (Figure 8). This is an indication of how well the dominant and non-dominant hand perform the same subtask (pick, pass, place) comparatively. An ambidexterity difference of zero indicates perfect ambidexterity (no difference whatsoever). A difference of ten indicates that the weaker side is 10 seconds slower. Note that the weaker side need not be the same for each of the subtask (e.g. dominant hand could be weaker for picking a peg and your non-dominant hand could be weaker for placing a peg). The ambidexterity difference takes into account the weaker side for each subtask. It appears that some degree of ambidexterity is necessary to attain proficiency but is not a sufficient skill by itself. Literally, subjects can be equally slow with both hands.

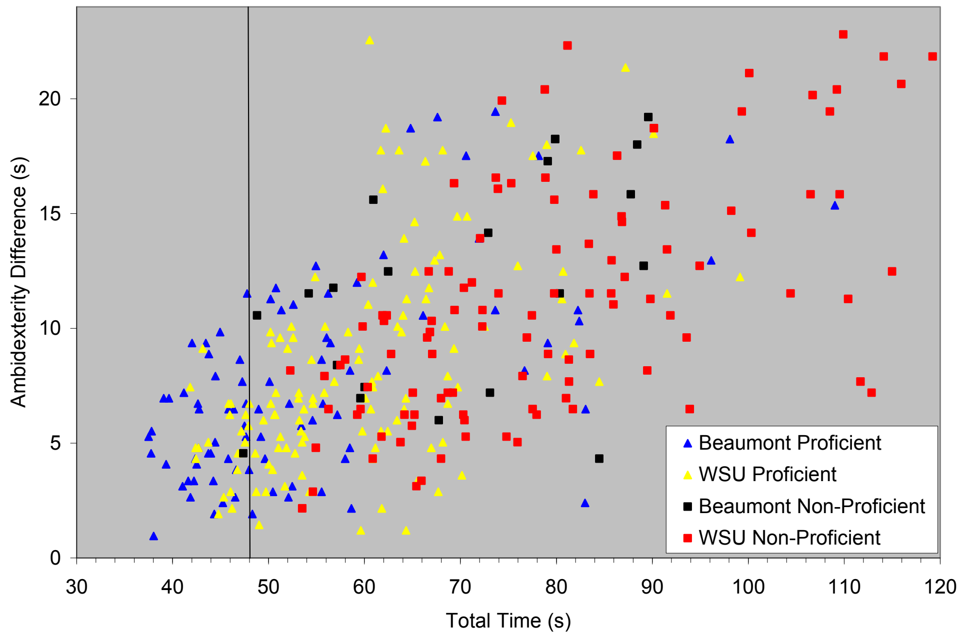


Figure 8: Scatter plot of the ambidexterity difference vs. total time for the peg transfer task. Some degree of ambidexterity is necessary to attain proficiency but is not a sufficient skill by itself.

<u>Task Refinement:</u>
We have also added an additional adjacent task to the standard FLS known as a secondary distraction. In this scenario, the subject's primary task is to perform the FLS task. Their secondary task is to perform a pattern recognition task. This is intended to measure the extent of automaticity of task performance, the ability to successfully perform the task without full attention, that FLS metrics do not currently measure. Automatic movements will continue on task, despite distractions. The degree of automaticity in the performance of a task may translate into the real-world OR better than primary measures such as speed. Measuring automaticity may also be useful in the evaluation of skill degradation. Secondary skills may degrade before or to a greater extent than primary skills, when measured on a simple task such as peg transfer.

The pattern recognition involves looking at an adjacent window/screen and recognizing when a circle appears 3 consecutive times on one side of the window (Figure 9). The subject presses a foot pedal when this occurs. The circle appears every second for 0.3 seconds at a time. The task is relatively simple to perform by itself. The task requires constant attention with respect to the secondary window while performing the primary task. If the subject's entire attentional resources are devoted to the primary task, the subject will most likely fail the secondary task. Stefanidis et al. (Do Novices Display Automaticity During Simulator Training? The Journal of American Surgery 2008 195: 210-213.) has indicated that this is a possible metric to distinguish between novices and experts that have the same trial times.

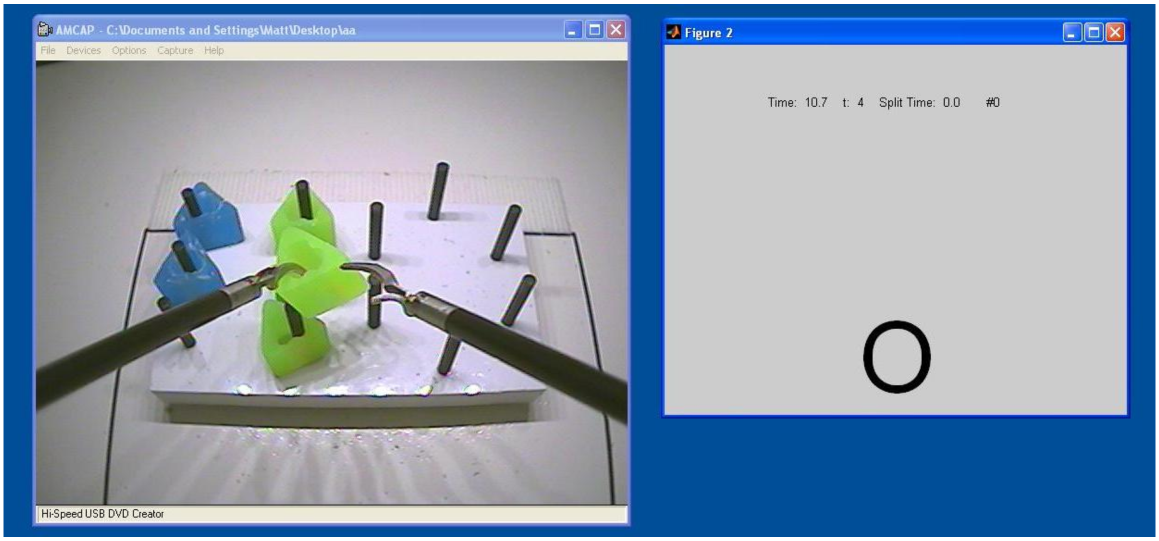


Figure 9: Screen shot of the peg transfer task along with the secondary distraction task (pattern recognition). The circle appears at either the top or bottom of the window. Subjects have to recognize when it appears on one side three consecutive times while performing the primary task on the left hand window.

Another metric that might be predictive of how subject success on a secondary task is the parallel ratio. This is a measure of how much close the pick and placement of pegs occur. Ideally, the subject would be able to pick and place pegs at the same time. This requires splitting your attention between two tasks simultaneously (picking and placing a peg) similar to performing a task with a secondary distraction.

There were two main strategies that subjects employed in trials currently analyzed. One was working in series, meaning that they do a single subtask (pick, pass and place in that order) one at a time. Ideally, this would result in a parallel ratio of 2. The other strategy was to work in parallel meaning that you are trying to pick and place pegs concurrently. Ideally, this would result in a parallel ratio of 1.

Subjects who were proficient spanned a wide range of parallel ratio indicating that both strategies could be used successfully to complete the task (Figure 10). More importantly, employing a parallel ratio does not equal success as the Wayne State non-proficient subjects (red squares) got very low parallel ratios but no proficient times. This indicates that the subject was consciously trying to work in parallel but was not sufficiently fast enough to reach the goal using this strategy. However, parallel ratio could predict how subjects fare on the same task with the secondary distraction since it requires splitting your attention between two windows or screens.

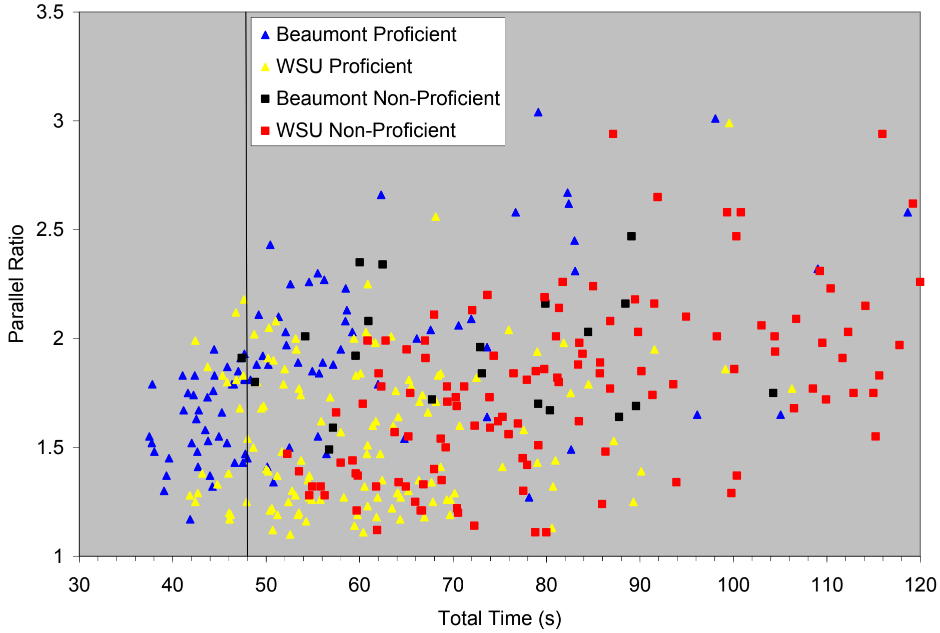


Figure 10: Scatter plot of the parallel ratio vs. total time for the peg transfer task. The degree of parallelism seems to have no bearing on proficiency but it might on the secondary task performance due to the splitting of attentional resources required for doing tasks in parallel.

<u>Circle Cutting Task:</u>
For the circle cutting task, preliminary data from novices has been analyzed by training day. Figure 11 shows the learning curve broken down by training day for one subject. The mean time for the day is also shown.

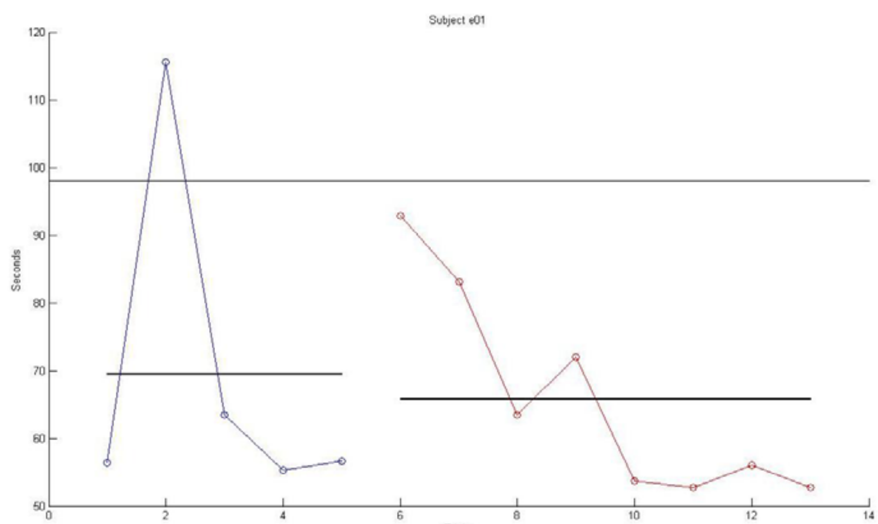


Figure 11: Learning curve for one subject broken down by their two training days. The thick black horizontal lines indicates the mean trial time for that day.

TASK 3: **Describe a methodology and provide preliminary data to document individual-specific laparoscopic skill deterioration during prolonged absence**

There have been a number of logistical challenges relating to navigating the multiple IRBs required to complete this study. Moreover, technology development time and funding limitations have limited our ability to explore the impact of prolonged absence on skill degradation on subjects who have reached proficiency. Moreover, this preliminary work demonstrates that the impact of automaticity on skill retention needs further exploration. In terms of surgeon readiness, this implies that the most appropriate test population to accurately measure the impact of prolonged absence on skill degradation is a population of military surgeons pre- and post-deployment. Collecting the preliminary data for later comparison with post-deployment evaluations is beyond the constraints of funding and duration of this project and would have to be the subject of future trials.

TASK 4: Describe a methodology to employ augmented reality technologies to support individual-specific retraining of basic laparoscopic skills following prolonged absence

Task 4 involves the translation of surgical assessment to the training of the surgeon. Utilizing advanced augmented reality techniques first developed to aid astronauts to learn and perform complex tasks in a difficult environment, we have implemented a tracking, assessment and augmented reality guidance system for training. Since we know the position and orientation of the tools (from the magnetic tracker) and position and orientation of the camera (fixed) then we can display augmented reality cues on the monitor to help the subject learn. Cues can be in the form of coordinates, or text or where to go next. We have demonstrated the ability to place any simulated 3D graphics object within the view of the FLS camera.

Augmented reality provides the most clinical utility when it can be combined with tasks such as intracorporeal suturing. Intracorporeal suturing is a task that is difficult to master and rarely practiced, even by surgeons with significant laparoscopic experience. Learning intracorporeal suturing would provide significant clinical value to these surgeons, and is very suited to instruction and practice using simulation. This task is the next we have automated in our sensor.

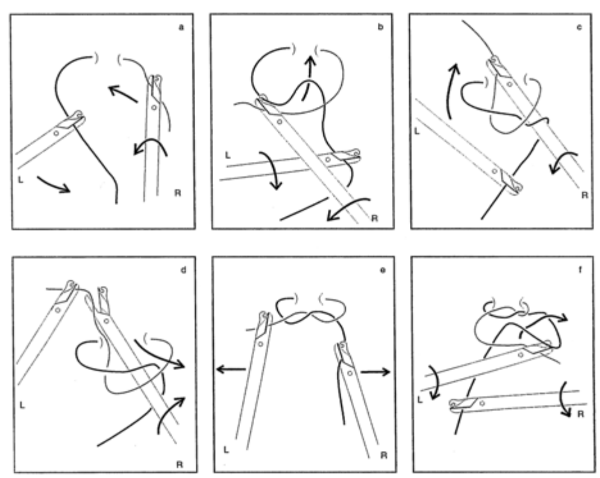
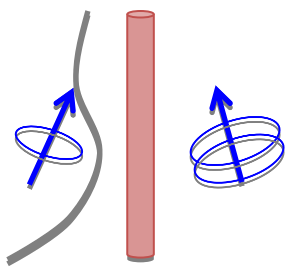


Figure 12: Steps in the hand-tie method of forming an intracorporeal knot involve several instrument transfers. Reprinted from Murphy, DL, Annals of Surgery Vol. 234, No. 5, 607–612.

As shown in the Figure 12, intracorporeal knot involves a complex set of motions and hand-eye coordination skills. The motion analysis software for intracorporeal suturing analyzes the 16 different ways to place a square knot using laparoscopic intracorporeal techniques and the 5 to 10 different general motions involved for each knot

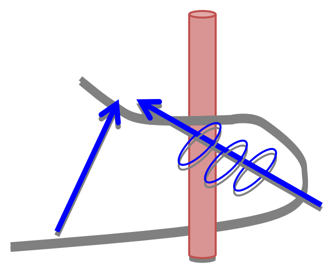
Intracorporeal knot tying motions are broken down within the vector tracking algorithm into repeated half-knots with five major components in each half-knot. The basic motions are (A) grasp suture end, (B) crossover, (C) rotate grasping instrument in the correct direction (D) grasp suture tail and pull through, and (E) tighten. These motions can be tracked and broken up into a series of integrated kinetic event vectors. Ten motions are required for a complete square knot: 4 grasping motions, 2 rotations, 2 crossovers, and 2 tightening motions. Motion parameters for each knot-tying event are traced utilizing the three-dimensional motion tracking system. For each motion, an analysis of motion constraints is developed.

A



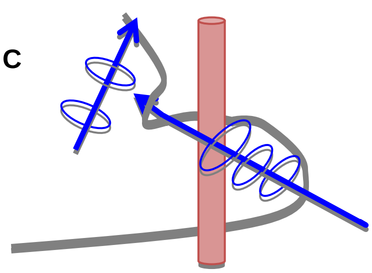
Grasping motion with left instrument

B



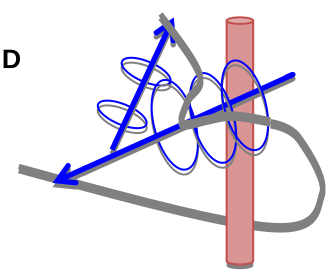
Crossover motion of right instrument

C



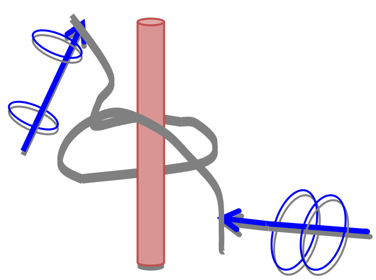
Clockwise rotation of right instrument, wrapping suture

D



Grasping motion with right instrument to capture suture tail

E



Pulling motion with both instruments to tighten half-knot

Figure 13: Piecewise motion vectors for intracorporeal half-knot tying are shown in blue. Suture (grey) and simulated vessel (red) are shown for clarity.

The parameters resulting in a successful knot are analyzed based on time and the effectiveness of the knot. Delayed or improper knot tying is analyzed step by step to determine the 'weak link' in the technique. Repeated knots are analyzed and three-dimensional motion representing successful technique is generated with boundary conditions established. The centroid of the piecewise motion is determined as best practice motion. The five piecewise vector motions that are combined for a completed half-knot are shown in Figure 13.

Training for intracorporeal knot tying is ideally suited to demonstrate the ability of augmented reality to guide the novice with coordinate cues learned from best practice techniques of experts. The augmented reality algorithm will integrate motion tracking during novice performance with the best practice motion analysis using the instrument path data from expert surgeons. This overlay will help guide the novice in correct and efficient instrument movement by providing a visual and/or auditory cue when the path of their instruments deviate beyond the expert pathway overlay. A predicted motion boundary analysis is formed to visually guide the motion within acceptable parameters. When the novice surgeons' technique is within the proper parameters the cues in the coordinate system show a blue color. Deviation from the best practice boundary conditions results in a change in the coordinate cues to red.

Toward this end we have developed an algorithm that transfers the motion kinetics for intracorporeal knot tying to an augmented reality platform. This software assesses the tracking motion in each trial; successful attempts are registered as positive, and out of bounds motions are assessed as negative outcomes. This algorithm will be used to gather data to set parameters of correct motion for the task. In addition the tracking will include timing as an assessment of efficiency. When combined, a best practice guidance parameter will be established for real time feedback on motion kinetics. A flow diagram of this algorithm is outlined in Figure 14 below.

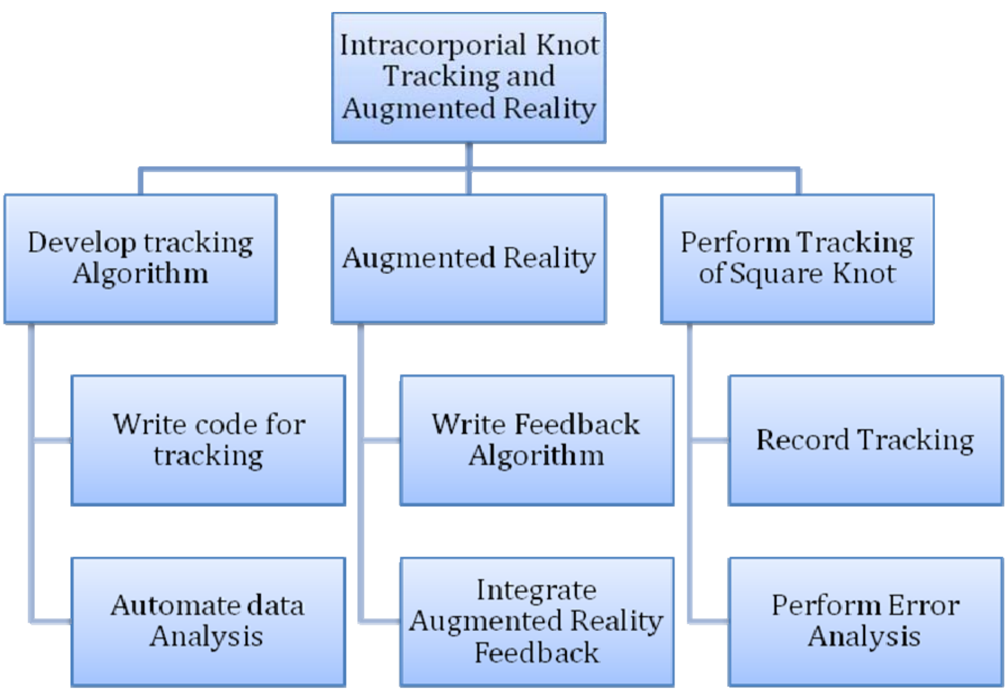


Figure 14: Flow Diagram of laparoscopic intracorporeal knot task used for tracking and augmented reality feedback.

In order **provide student f**eedback and analysis of the intracorporeal knot tying we hav e developed a learning neural network algorithm.

The software tracks the motion and compares the best vector orientation for proper and efficient knot tying. The tracking data from each trial and analysis of the resulting knot is input into the algorithm to determine the kinetic motion and axial quadrants that work or fail to work. Analyses of failed attempts are compared to the piecewise motion of successful attempts and a generalized coordinate system is established for each portion of the motion. Variation outside the boundary of the allowed motion generates an alarm in the augmented reality program via a change in color in the coordinate overlay. This is combined with average time to tie and a best practice path is learned. A virtual avatar of the grasp and motion can also be overlaid in the visual field for proper training. The logic diagram for this is outlined in Figure 15.

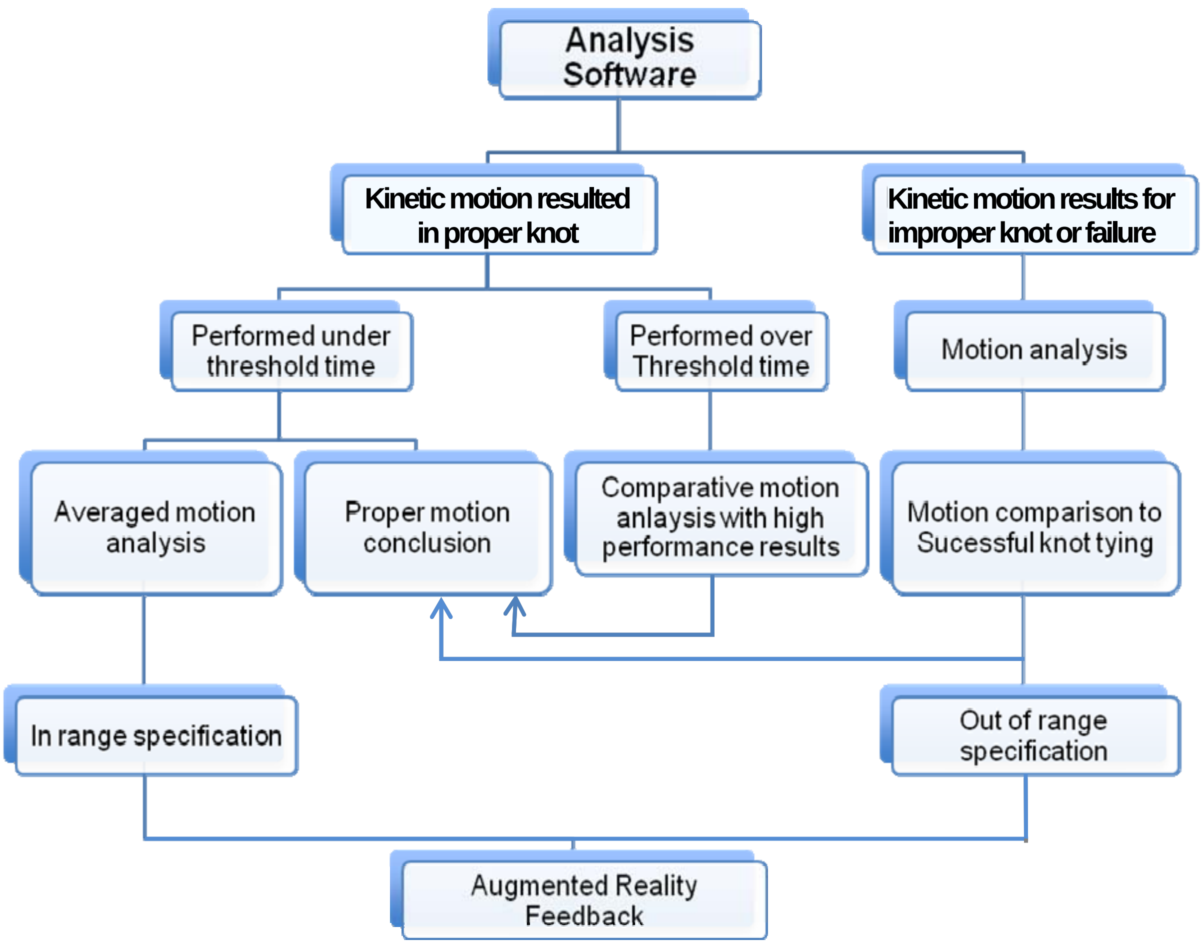


Figure 15: Logic diagram for analysis software for motion analysis and augmented reality information input.

An additional camera system was added to allow for three-dimensional visual tracking as related to the coordinate tracking via magnetic sensor position location. Software for

image analysis tracking was integrated with the position tracking. The software allowed edge detection by machine vision for automated position location. A tubular phantom was added for a standard knot tying exercise. The optical system and magnetic tracking position sensing system was calibrated utilizing known location touch points. Additional software was implemented to indicate differences in left hand and right hand proficiency.

The most recent work on this project focused on developing error analysis software capable of correlating kinetic motion tracking with errors, failures and delays in knot tying. The software also performs a differential analysis between speed and error rate for right hand verses left hand performance. This software was used to analyze 50 test cases. The scatter plot with best practice analysis overlay is shown in Figure 16a. In each case errors were identified visually and translated to the error analysis software. For example, the left hand and right hand motion was broken up into five piecewise vector motions. The best practice best time example was used as a standard. Motion was compared to the best practice motion at each of the five vector motions. Figure 16b shows five separate time segments of the best practice trial corresponding to the five vector motions.

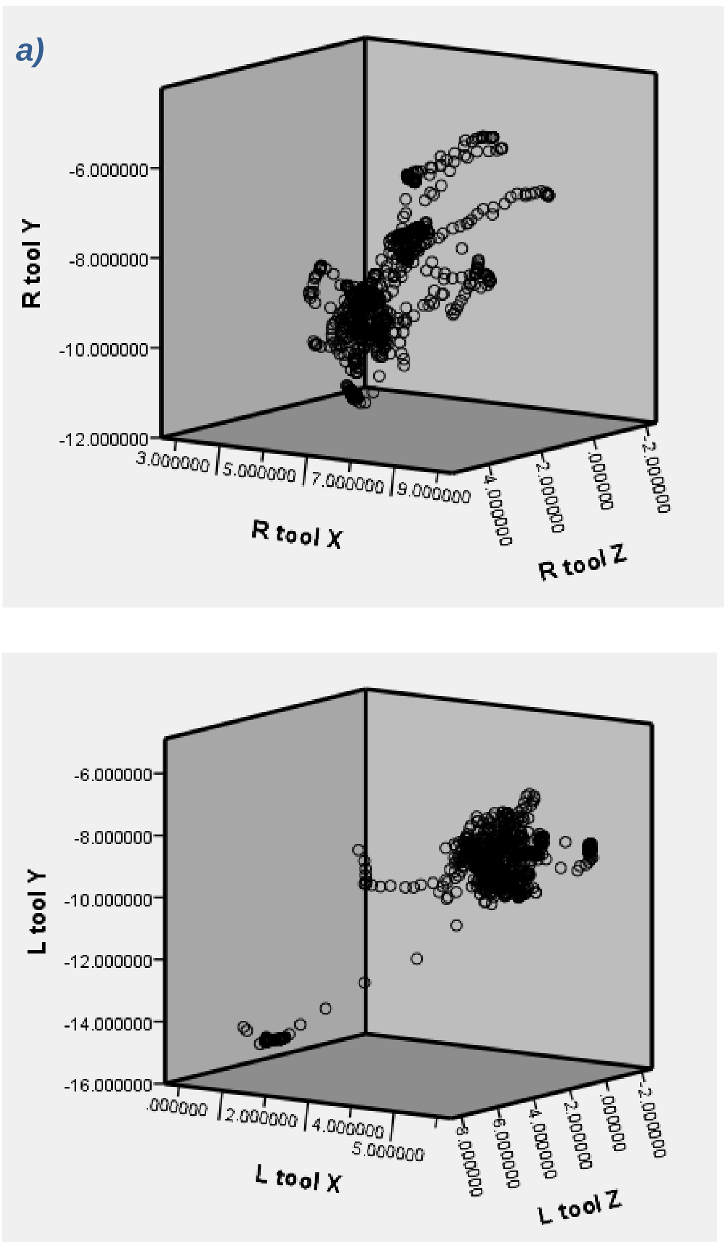
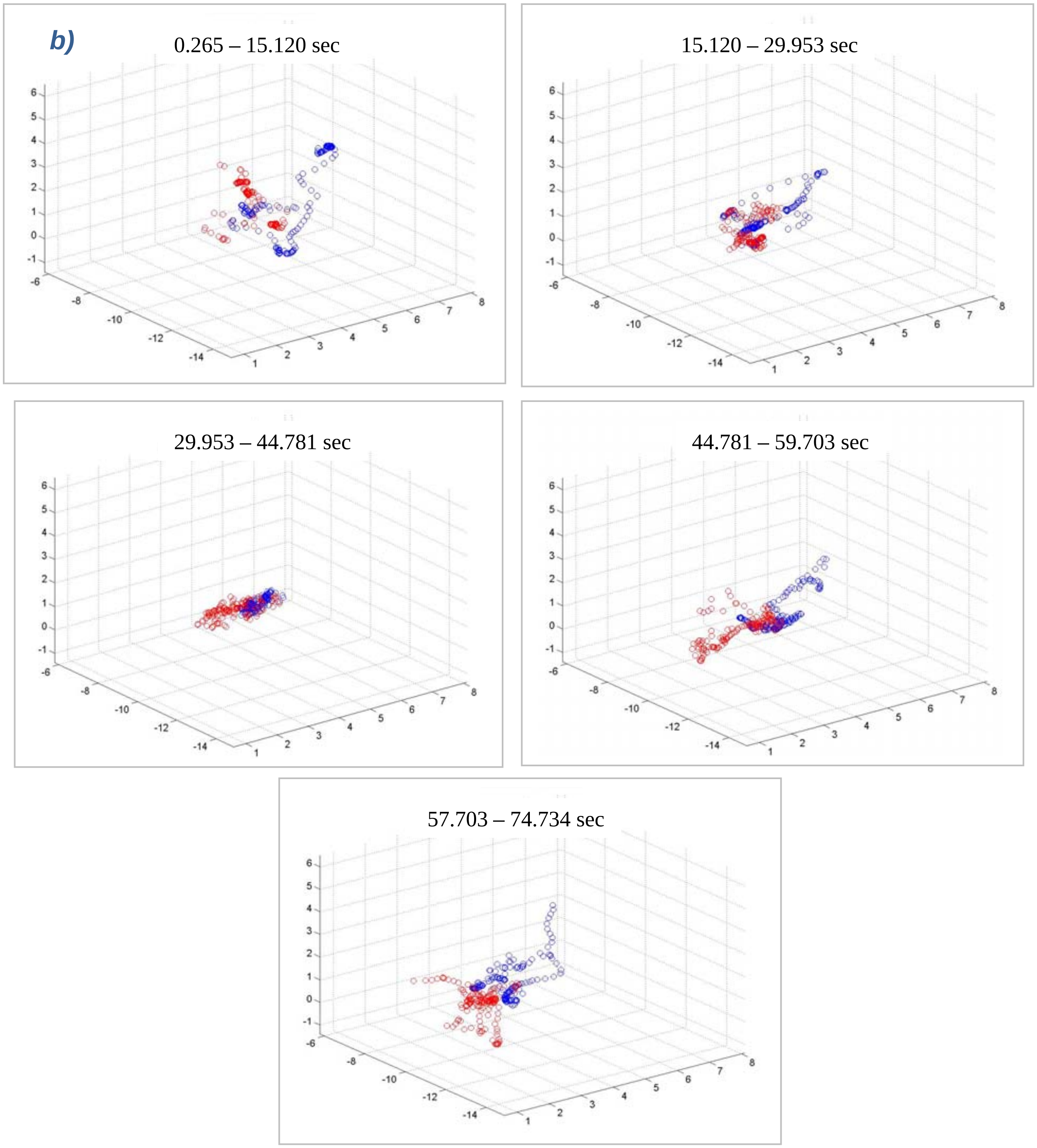


Figure 16: a) Scatter plot of 50 trial cases for intracorporeal laparoscopic knot tying.

Upper: left hand motions.
Lower: right hand motions.



b) Best practice example average, over 5 time segments, for translation into augmented reality guidance. Left hand data is shown in red, right hand data shown in blue.

Both variations of each vector motion and time to complete were compared to the best practice example. All successful knot tying motions were compared to best practice example to determine allowable variability in each piecewise vector motion to be used in the augmented reality overlay. The edge detection path shown in Figure 13 represents

the virtual reality overlay guidance path for each of the five stepwise vector motions in knot tying. This overlay is used for training as a best practice and for error-detection.

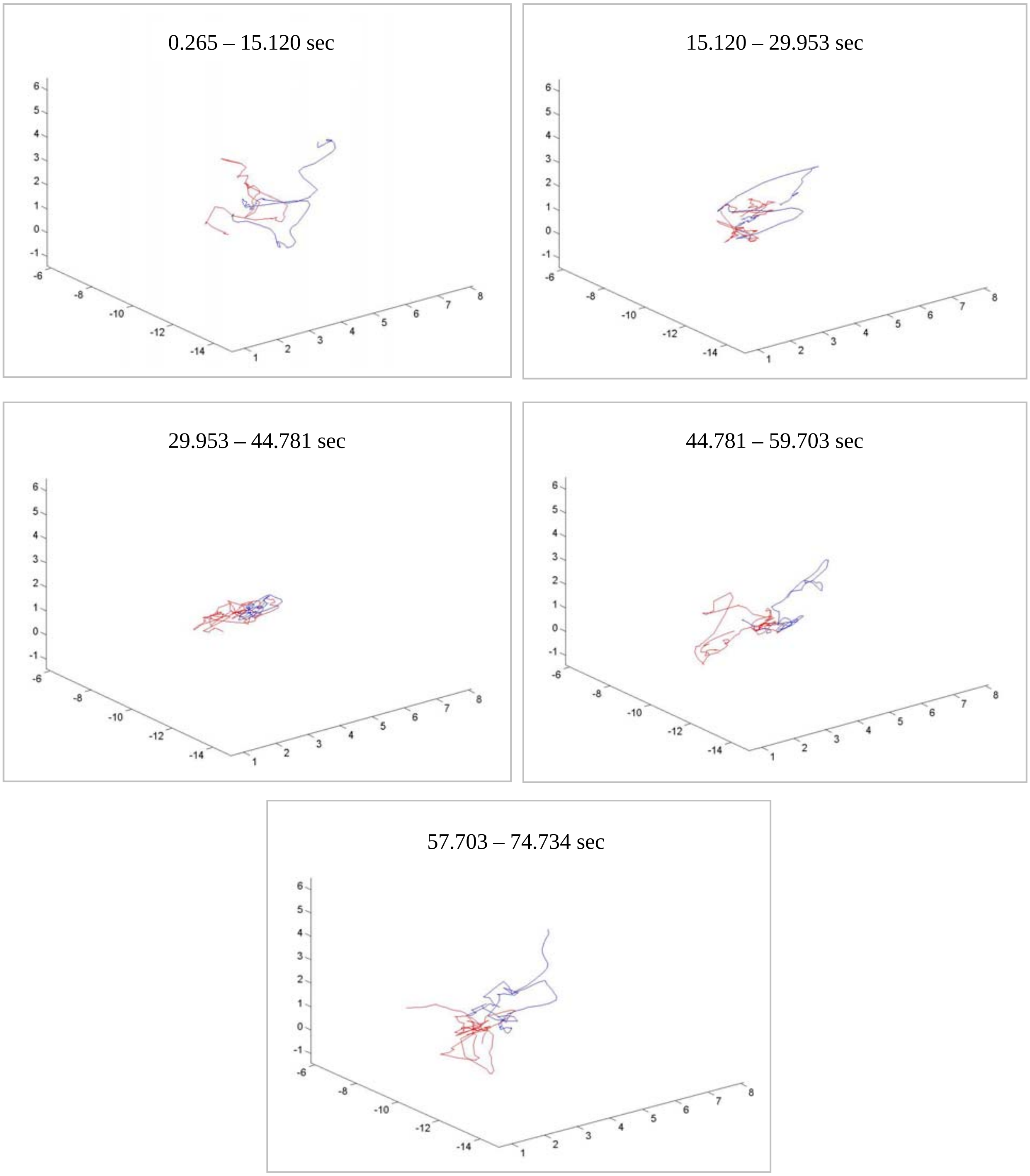


Figure 17: Edge Detection showing path for augmented reality best practice. Similar to Figure 16 above, the left hand data is shown in red and right hand data is shown in blue.

KEY RESEARCH ACCOMPLISHMENTS

- Determination of surgical skills to be tested based on the FLS curriculum
- Development of a prototype simulator and instrumentation with magnetic sensors
- Software development for the FLS peg transfer and pattern cutting tasks for error detection and performance metrics capture
- Creation of new objective metrics for the FLS peg transfer and pattern cutting tasks
- Skills task refinement including secondary distracters
- Pilot testing and system verification
- Expert and Novice subject testing and data analysis
- Refinement of instrumented simulator setup to incorporate additional cameras for 3D data collection
- Development of an integrated algorithm to transfer FLS kinetics for intracorporeal knot tying to augmented reality
- Development of error tracking analysis software for feedback with augmented reality.
- Integration of image tracking hardware, augmented reality overlay and error detection algorithm
- Refinement of data reporting software

REPORTABLE OUTCOMES

1. Reports, manuscripts, abstracts:

   Dage M, Cao A, Pandya A. Data Driven Optimization of Surgeon Skills. 2010 Wayne State University Undergraduate Research Conference, Detroit, Michigan, Nov. 12, 2010.

   Ali N, Stefaniak J, Robbins J, Cao A, Dage M, Pandya A, Auner G, Shanley C. Data-Driven Optimization of Surgeon Skills for Enhanced Training, Simulation and Assessment. AEI Consortium of the American College of Surgeons 4th Annual Meeting, Chicago Illinois, April 29-30, 2011.

   Shanley C and Auner G. Toward Novel Simulation-based Proficiency Metrics for Surgeon Skills Training and Assessment. Medicine Meets Virtual Reality (MMVR-18), Newport Beach California, February 8-12, 2011.

2. Degrees and research training opportunities: undergraduate and graduate students at the SSIM laboratories, Wayne State University, have been involved in the simulator and software development and refinement. Surgical residents have been involved in design critique, data collection and analysis at William Beaumont Hospital.

3. Collaborative funding applications related to work supported by this award: None

4. Related projects and collaborations initiated: The collaborative team is currently exploring additional projects involving the correlation of traumatic brain injury with force data obtained from smart acceleration sensors in military headgear joint with Lockheed Martin Corporation.

CONCLUSIONS

Creation of an integrated sensing system with laparoscopic surgical tasks based on the FLS curriculum, and generation of task metrics to evaluate skill proficiency has been accomplished. Analysis of data on peg transfer and circle cutting tasks resulted in enhancement of the skills testing environment. We anticipate that the data collected with this new system will allow refined analysis of FLS tasks. The system will allow the users and evaluators to understand particular task deficiencies at a more detailed level. This refined analysis will also allow the system to distinguish novice from expert subjects based on performance measures, and also determine any degradations in skill levels as compared to previous attempts (i.e. prolonged absence).

There has also been significant progress toward implementing a virtual reality overlay for training and evaluation of intracorporeal knot tying skills. A computer algorithm was developed to assess data from the FLS to track the intracorporeal knot tying as a complex skill, with error tracking and subject feedback. The goal is to create teach the algorithm best practices, with variations, for intracorporeal knot tying and translate that to an augmented reality enhanced FLS trainer. This would allow for real time visual feedback and guidance during the learning process and assessment of skill.

Significance:

- The overarching goal of this research is to improve military surgeon readiness and enhance patient safety. We believe this novel technology provides an objective, data-driven platform upon which complex, proficiency-based technical skills can be assessed, monitored and improved over time. This platform will facilitate the validation of individual performance metrics that can be used to monitor proficiency. It will also facilitate the development of curricula to enhance individual performance, promote maintenance of proficiency and to facilitate specific retraining following periods of prolonged absence from surgical practice.
- The development of the motion kinetics assessment from the FLS tracking system has been completed as a major step toward integrating augmented reality feedback and guidance. Successful integration of an augmented reality overlay with our instrumented simulator provides proof of concept that we can define an envelope of performance based on the efficiency of expert motions, and has implications for both skills degradation evaluation and novice training.
- Similar techniques may be applied to more complex tasks, such as surgical subprocedures like bowel anastomosis. Several simulation centers are applying simulation to specific technical skill accomplishments. (For example, difficult airway management.)
- Very little work is being performed in performance validation of skills, integration of technical and cognitive skills, and the integration of team skills

- As these performance metrics are established there will be a tremendous demand for performance-based certification of healthcare professionals. Markets would include:
    - Certification organizations
    - Educational institutions
    - Ongoing requirements for proficiency of healthcare professionals (Privileges, etc.)